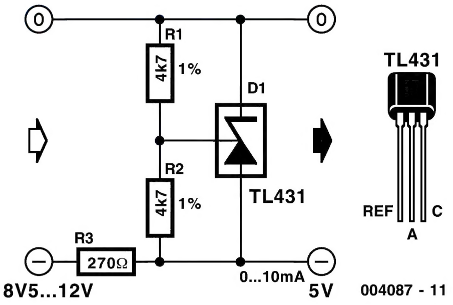
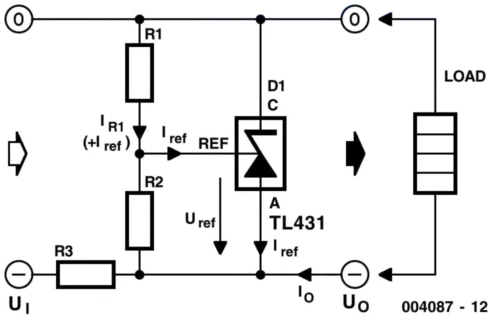
018 Negative Shunt Regulator





K. Thiesler

Using just a few components and the circuit shown (**Figure 1**) it is possible to build a regulated negative supply with an output voltage of –2.5 V to –36.0 V with an output current in the order of 100 mA. The TL431 shunt regulator from Fairchild Semiconductor has good accuracy and only requires an unregulated negative voltage source. The Drop-out-voltage (Vin – Vout) of the regulator appears across resistor R3. The shunt regulator must always have a load connected at its output.

The negative output voltage is set by the voltage divider formed by R1/R2

$$U_O = (1 + R1/R2)\cdot U_{REF} + R1\cdot I_{REF}$$

where
U_{REF} = –2.495 V (nominal)
I_{REF} = –2 μA

This gives the relationship between the output voltage, the voltage divider network and the internal voltage reference of the TL431.

To ensure correct operation, the current through the divider network (I_{R1}) must be many times higher than the reference current (I_{REF}) the value of R1 is given by:

$$R1 = (U_O - U_{REF}) / I_{R1}$$

So choosing an output voltage of –5 V and using an I_{R1} of –100 μA i.e. 50 times I_{REF} gives a value for R1 of:

$$R1 = (-5\text{ V} - 2.495\text{ V}) / -10^{-4}\text{ A} \approx 25.05\text{ k}\Omega$$

The second resistor is given by:

$$R2 = U_{REF} / [(U_O - U_{REF})/R1 - I_{REF}] \approx 25.46\text{ k}\Omega$$

For correct operation of the regulator the value of cathode current must be between –1 mA and –100 mA, and the load current should be constant. Both currents flow through R3 and are used here to estimate its value:

$$(U_{Imin} - U_O)/(I_{Omax} + I_{Cmin}) \geq R3 \geq (U_{Imax} - U_O)/(I_{Omin} + I_{Cmax})$$

Using the minimum resistor values will obviously increase the power dissipation in the circuit. The power dissipated in resistor R3 is given by:

$$P_{R3} = (U_{Imax} - U_O)^2 / R3$$

The power dissipated in the regulator is given by:

$$P_{TL431} = U_O\cdot I_{Cmax}$$

If an output voltage of –5 V is required then calculations becomes a bit simpler, R1 and R2 will be of equal value and the formula reduces to:

$$U_O = -2\cdot U_{REF} - R1\cdot I_{REF}$$

$$R1 = R2 = (U_O + 2\cdot U_{REF}) / I_{REF}$$

With a nominal reference voltage (U_{REF}) of –2.495 V this gives a resistor value of 5 kΩ. Changing this value appreciably will alter the reference current and therefore the output voltage. The diagram in **Figure 2** gives the complete circuit with component values for a –5 V voltage regulator.

There are three versions of this chip from Fairchild that improve on the U_{REF} specification. The standard TL431 with no suffix has a U_{REF} tolerance of ±2 %, while the A suffix has ±1 %, and the **L** suffix has ±0.4 %. A data sheet (albeit with a few typos) can be downloaded from the Fairchild website:
http://www.fairchildsemi.com/ds/TL/TL431.pdf
Maxim also produce a similar device with fixed output voltages. The MAX6330 and MAX6331 is available in 5.0 V, 3.3 V and 3.0 V versions, with an output current of 100 μA to 50 mA. The voltage divider network is integrated on the chip.

(004087)